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One Year's Processing and Interpretation—An Overview[1]

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A total of 201 complete television frames of Mars were returned by Mariners 6 and 7 in late July and early August of 1969. During the subsequent year over 3500 different versions of those frames were generated by computer processing involving the production of about 35,000 individual photographic prints and large amounts of computer printout as well. This extensive data processing and distribution required the significant participation of about fifteen scientists, engineers, and technicians, mainly at the Jet Propulsion Laboratory. During that same year, the processed data were analyzed and interpreted by approximately twenty-five scientists and technicians at six different institutions. The special supplement of which this is the introductory paper presents most of the scientific findings that have accrued during the first year following the Mariner 6 and 7 flybys of Mars. It constitutes a final report on the television experiment, although significant efforts are continuing. Preliminary results were presented in three papers published in August and October of 1969 [*Leighton et al.*, 1969*a*, *b*, *c*]. *Smith* [1970] presented information about the size, shape, and surprisingly low albedo of the martian satellite Phobos. Information concerning various aspects of the camera and data systems has also been published recently [*Danielson*, 1970].

[1] Contribution 1894, Division of Geological Sciences, California Institute of Technology, Pasadena.

NATURE OF THE DATA

The nomenclature used here to designate the various pictures is the same as that used previously [*Leighton et al.*, 1969*a*, *b*, *c*]. The two cameras, of focal length about 5.0 cm and 50 cm, are respectively designated A and B. the approach of each spacecraft toward Mars and its close passage past the planet are designated far-encounter (FE) and near-encounter (NE). The pictures in the FE period (taken only by the B camera) carry a designation of the type 6F43, denoting the 43rd picture taken during the FE approach of Mariner 6. Similarly, 7N17 denotes the 17th picture taken during the NE period of Mariner 7. In addition to the FE and NE periods, an intermediate period, called the late-far-encounter period, (LFE), is defined for Mariner 7. During this LFE period, 88 digital pictures were transmitted to earth in real time from both A and B cameras as a special addendum to the scheduled mission. These pictures turned out to be uniquely useful for studies of the color characteristics of atmospheric scatterers and of the light and dark surface markings.

The design characteristics and calibrated properties of the four camera subsystems are summarized in papers by Danielson and Montgomery and by Rindfleisch et al. in this section. The camera fields, projected on the planet during the NE phases of the two missions, have been published [*Leighton et al.*, 1969*c*]. They are also shown in photomosaic form in papers of this issue.

The camera subsystems and data format were designed to maximize the total useful data return from the mission, under the existing limitations of data storage volume, communication bit rate, etc., and under the rather poorly defined conditions of visibility of the martian surface as these were known. Thus, a hybrid analog-digital data-recording scheme was used to maximize the total number of bits returned, and the on-board electronic signal processing and digitization were designed to assure the successful recording of low-contrast detail, expected on the basis of the Mariner 4 results. The resulting data required rather extensive and complex computer processing subsequent to their receipt on earth, to reduce them to photometrically accurate form. This processing is described in the paper by Rindfleisch et al.

Although picture processing is not yet complete, particularly with respect to ultimate photometric precision, the procedures have been carried sufficiently far to justify general dissemination of the pictures for scientific use. Thus, a photometrically decalibrated version, and one or more maximum-discriminability versions, of each FE and NE picture from each spacecraft have been placed on file at the National Space Science Data Center (NSSDC) in Greenbelt, Maryland. Copies may be ordered from that data center.[2] The photometric decalibration of the pictures (that is, the correction of the received data using calibration data taken prior to launch) has been carried as far as possible on the basis of prelaunch calibration data. However, certain inaccuracies and inconsistencies are known to remain, owing, perhaps, to changes in the vidicons or electronic systems during flight, contamination, degradation, slight maladjustments of the optical systems during launch or flight, or other causes. Further improvement of the photometric fidelity of the pictures will require intercomparison of results from the four cameras and checking of the apparent photometric intensities observed for physical consistency. Young and Collins describe some preliminary applications of the data to define the photometric properties of selected areas of Mars and demonstrate genuine variations in photometric function from place to place on Mars.

A further aspect of picture processing concerns the geometrical fidelity of the images. As received, the images are subject to several per cent distortion of rather complex nature, mostly traceable to nonlinearities in the electronic beam-deflection functions of the camera system. Smaller but measurable distortions are associated with the video-to-film conversion equipment by which the final output pictures are produced. These distortions were mapped and reduced by computer processing to levels that are acceptable for most purposes; the apparent and true locations of a given image point, which may have differed by 10 or 20 pixels in the 'raw' picture, will have been brought within one or two pixels of one another in the processed versions. A more accurate geometric correction program that should reduce the distortions to a level well below one pixel, is still in process. Some of the properties of the camera systems and picture processing procedures that bear on the geometric corrections are included in the paper by Danielson and Montgomery and in that by Rindfleisch et al.

One of the principal uses of geometrically corrected pictures is in cartographic applications of the data. Davies and Berg describe the progress to date of a program to establish an areodetic control net from the Mariner pictures; these pictures provide the first opportunity to establish a truly *topographically* based control net for the planet, as distinguished from a net based only on the light and dark features.

Another interesting, and potentially powerful, application of computer processing to geometrically corrected pictures is the production of a map-like projection of the pictoral data. Cutts, Danielson, and Davies describe a preliminary version of a Mercator photomap of Mars, composited from several individual frames. A more

[2] National Space Science Data Center, Goddard Space Flight Center, Greenbelt, Maryland 20771.

extensive rendition, in which data sequences of overlapping frames will be superimposed and averaged, is in process.

Practical considerations associated with prelaunch operations led to the use in mission operations of a convention for longitude different from that normally used by astronomers. In the project version, longitudes are expressed in degrees east or west from the central meridan up to 180°. Later versions of our picture data are being converted back to the traditional form with longitudes expressed as degrees west of the central meridan up to 360°.

SURFACE AND ATMOSPHERE OF MARS

Mariner 4 provided a glimpse of about 1% of the martian surface at a resolution of about 3 km. Mariners 6 and 7 not only extended that kind of glimpse to more than 10% of the surface with the A cameras, but also provided an even higher resolution view (0.3 km resolution) by means of B frames nested within the broader coverage of the A frames. In addition, all this coverage was supplemented by global coverage of the entire disk acquired with the B camera over several days prior to encounter. These 143 frames of the far-encounter phase have provided the essential tie between nearly a century of low-resolution (~100 km resolution) earth-based observations of the planet and the highest-resolution images returned by the flybys. Thus essential questions that have been addressed by the Mariner 6 and 7 television team include, What is the nature of the light and dark markings? Are there 'canals' and 'oases'? Is the polar cap really a surface deposit? Is there a 'polar collar'? Is there an atmospheric 'blue haze'? These and other related questions are discussed principally in three of the papers of this supplement: (1) 'The Surface of Mars, 3, Light and Dark Markings,' by Cutts et al.; (2) 'The Surface of Mars, 4, The South Polar Cap,' by Sharp et al; and (3) 'Mariner 1969: Atmospheric Results,' by Leovy et al. In those papers, it is found that the 'blue haze', the polar collar, and the canals are not confirmed. The south polar cap, on the other hand, is found to be a surface deposit and is possibly much thicker in places than previously predicted by *Leighton and Murray* [1966]; the possibility, present and past, of permanent ice fields is speculated on as well. Furthermore, the cap edge was found to be within 1° of its predicted position (for the appropriate longitudes), lending enhanced credibility to the collected earth-based data chronicling its migration. Boundaries of the dark areas Meridiani Sinus and Sabaeus Sinus with adjacent areas are found to include three distinct types, and topographic control of the boundaries is evident. Where the near-encounter frames cross those boundaries it appears that a thin deposit of light material may be transported onto adjacent dark areas.

Near-encounter views of the planet show it surprisingly free of optically thick clouds; thin hazes, on the other hand, are found both on the limb and near the terminator, as discussed by Leovy et al.

Near-encounter views of the terrains of Mars reveal the existence of uncratered terrains (Sharp et al.) as well as a preponderance of cratered terrains (Murray et al.). The mare/upland dichotomy of the moon is not found on Mars. The uncratered featureless and chaotic terrains appear to be the sites of unknown, but recently active, erosional processes. The featureless area Hellas is located in a structural basin of great antiquity, whereas the chaotic terrains are possibly a relatively recent addition to the surface of Mars. Either the Hellas area or the chaotic terrains, or both may be surface expressions of localized internal activity. In any case, Murray et al. argue that the large, highly modified craters generally present over the surface of Mars include survivors from the final phases of planetary accretion, as do the lunar uplands. However, they conclude postaccretion crater modification persisted longer on Mars than on the moon and involved greater horizontal redistribution of material by processes not understood at present. The smaller, fresher craters seen in the B frames were formed over some subsequent period of time by an impacting flux differing from that recorded on the lunar maria by being relatively deficient in large bodies. If portions of the present topography of Mars have indeed survived from the end of planetary accretion, it would seem unlikely that Mars ever experienced a terrestrial phase in which primitive oceans could have been present.

IMPLICATIONS FOR SUBSEQUENT MARTIAN EXPLORATION

These results carry two kinds of implications for future missions: procedural and scientific.

Mariners 6 and 7 produced two hundred times the picture data of Mariner 4. The 1969 observations have required an amount of data processing and interpretation greater by an order of magnitude, as measured in terms of the number of people involved and of the separate versions produced. The two spacecraft scheduled to be placed by the United States in orbit about Mars in late 1971 are expected to return at least another one hundred times more picture data. Even allowing for the most optimistic improvements in efficiency of data processing, data handling and interpretation will constitute formidable tasks. Scientific interpretation still takes place in the minds of human beings, and that process clearly will be saturated by the output from the 1971 mission. Thus allowance must be made by both the planners of and the participants in such missions, not only to provide the requisite funds, but also to involve a sufficient number of dedicated scientists over a period of years to fully capitalize on such a scientific bonanza. By way of comparison, quantitive interpretation of the Mariner 6 and Mariner 7 picture data dealing with slopes and heights, planetary figure, color variations, and atmospheric scattering are still being vigorously pursued well over a year after receipt of the original data.

The results from Mariner 6 and 7 also carry scientific implications for the 1971 mission, some of which have been previously published [*Leighton et al.*, 1969*c*]. The features of the polar-cap area clearly warrant high priority, especially to obtain new pictures of the areas that were covered by frost when photographed by Mariner 7, as well as to explore for the first time the northern polar areas. The search for new kinds of terrain and for geographic variations in cratering history, as well as further investigations of those already discovered, are obvious objectives. And the intriguing clues to the light and dark markings provided by Mariners 6 and 7, such as evidence of local topographic control, hold promise that definitive answers may be forthcoming from the 1971 mission, especially from changing patterns of strong local markings that may be observable in repetitive photography of key areas.

Mariner 4 provided the first close-up glimpse of Mars and indicated that the Red Planet was more like the moon than the earth. Mariners 6 and 7 have revealed the handiwork of uniquely martian phenomena recorded on its surface. Perhaps the upcoming Mars orbiters in 1971 will unravel the nature of these surface processes sufficiently that our view of Mars will at last be freed completely from the mists of science fiction, and that Mars will stand by itself as a unique planetary object of intrinsic scientific significance.

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